UNITED STATES DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Washington, D.C. 20230

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
The Portals
445 Twelfth Street, S.W.
Room TW-A325
Washington, DC 20554

Re: Revision of Part 15 of the Commission's Rules Regarding Ultrawideband Transmission Systems, ET Docket No. 98-153 /

Dear Ms. Salas:

Forwarded to you for inclusion in the public record of the above-referenced docket, enclosed please find five copies of a Memorandum to the Chairman of the Interdepartment Radio Advisory Committee (IRAC) from the IRAC Representatives from the Department of Defense. The Department of Defense requested that the National Telecommunications and Information Administration provide these comments for the public record and for consideration by the Commission during its deliberations in this proceeding. A copy of the Memorandum was also submitted to the Commission's copy contractor, International Transcription Service.

Please direct any questions you may have regarding this filing to the undersigned. Thank you for your cooperation.

Respectfully submitted,

Kathy D. Smith

Kathy D. Smith
Chief Counsel

cc: International Transcription Service

Enclosures

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

1 October 2000

MEMORANDUM FOR CHAIRMAN, IRAC
Attn: Mr. Norbert Schroeder

FROM: MILDEP IRAC MEMBERS

SUBJECT: Comments on NTIA Draft Response to Ultra Wideband Transmission Systems NPRM (ET Docket 98-153)

1. The enclosed comments on the subject FCC UWB NPRM includes two attachments. Attachment 1 examines the impact of UWB emissions to an airborne radar receiver and Attachment 2 addresses a multi-function DoD earth station receiver.

2. GPS is a critical national asset. Therefore, we urge NTIA to ensure that no actions regarding UWB device use of the GPS frequency bands occur until tests and analyses have been completed.

3. There is extensive DoD use of critical 2200-2290 MHz receiving systems important to our nation. We are concerned that the 2 GHz upper limit proposed in the NPRM, below which additional power restrictions would become applicable, may not provide adequate protection for these sensitive operations.

4. Request that NTIA forward the enclosure and attachments to the FCC for inclusion in the public record as part of the overall Federal response to regarding the subject NPRM.

for Mr. Joe C. Capps US Army IRAC Member	for Mr. Bruce Swearingen USN IRAC Member	Mr. Nelson V. Pollack USAF IRAC Member

Enclosure:
Comments on FCC UWB NPRM with two attachments:
1. JSC EMC assessment of UWB devices and an airborne radar receiver
2. JSC EMC assessment of UWB devices and a multi function earth station

COMMENTS

[Note: In addition to the following comments, two analyses are attached.]

I. INTRODUCTION

The DOD welcomes the efforts by the FCC to encourage the use of Ultra Wideband (UWB) devices through the appropriate regulation of their use and technical parameters. The military would like to be able to use existing and planned commercial "mass marketed" low power UWB devices for many of the same reasons that they have potential for commercial market use. Additionally, we recognize that many of our Service members will want to use UWB technology within their homes on our bases and the public and private sector may want to bring UWB devices on our bases and installations. Also, many of our installations are adjacent to urban and suburban areas where UWB use can be extensive.

However, many Congressionally-mandated DOD functions are highly dependent on access to the RF spectrum. We must ensure that the use of these mass marketed devices, either commercially or by the government, will not present unacceptable performance degradation to DoD systems. This is especially true for critical DoD systems that must operate in the Part 15 restricted bands, e.g., sensitive earth station receivers, aids to navigation, etc.

The DoD agrees with the Commission's statement that "it is vitally important that critical safety systems operating in the restricted frequency bands, including GPS operations, are protected against interference." For example, we are concerned that GPS receivers might not be able to track and acquire GPS satellites in the presence of UWB signals. Specifically, we recommend that: (1) any ruling granting blanket approval of unlicensed UWB device operation in GPS or any restricted bands regardless of type of UWB use be deferred until after comments and replies are offered on all test data and results; and, (2) restrictions be placed on UWB devices operating below 2.29 GHz to the extent identified by the results of on-going tests and analyses to ensure protection of sensitive earth station receptions in the 2200-2290 MHz band and to protect reception of GPS navigation signals in the 960-1215, 1215-1300 and 1559-1610 MHz bands; and (3) the Commission adopt rules to ensure that the levels of UWB spurious and out-of-band emissions in bands below 2.29 GHz resulting from UWB devices operating above 2.29 GHz are kept below the levels identified as problematic as a result of testing and associated analyses.

The DOD urges the FCC to base any decisions on acceptable emission levels of UWB devices on credible analyses and measurements, and not on arguments emphasizing the lack of historical interference data from Part 15 unintentional radiators or on the past use of the limited number of currently available UWB-type devices. As the FCC is aware, past and present uses of Part 15 devices or UWB-type devices do not represent the potential future scenarios that may occur. These future scenarios must be evaluated for interference potential and the likelihood of them occurring assessed. Many of these analyses and measurements are ongoing, so the results are not yet available or analyzed. We therefore concur with the Commission's statement in paragraph 31 of the NPRM which states that, following the submission of test data, a public notice will be issued to provide an opportunity for comments and replies on the test results and analyses. On the other hand, we question whether the Commission's proposed October 30 target date for submitting test results provides adequate time to ensure that on-going and planned tests can be thoroughly completed and the results analyzed. The DoD notes that it is essential to ensure that tests results from both government agencies and manufacturers be completed to enable general consensus to be reached concerning the potential UWB interference impact to existing systems. We therefore urge the Commission to postpone any decision on granting unlicensed operation of UWB devices until both government and manufacturers test programs are complete and the results analyzed.

II. SPECIFIC COMMENTS

- **Paragraph 1:** In the summary, the statement is made that "UWB devices appear to be able to operate on spectrum already occupied by existing radio services without causing interference...". We believe that there is insufficient evidence, based mainly on the lack of mass-marketed UWB devices, to draw this conclusion at this time. The analyses and measurements underway and planned to address specific interference issues with systems in restricted bands will provide this evidence and may or may not support this conclusion. There is a distinct possibility that the degree of interference potential will vary among the systems in the restricted bands, leading to various alternatives regarding sharing in these bands.

- **Paragraph 19:** The commission requests comment on a proposal to accommodate very low power UWB devices within Part 15 of the FCC rules. We submit that comments regarding this proposal cannot be provided until measurements of UWB interference potential have been completed and the results analyzed.

- **Paragraphs 20 and 21:** The DoD supports the Commission in making sure that any initial rulemaking reflects a conservative approach. The NPRM proposes a definition where a UWB device operating below 6 GHz would have a fractional bandwidth greater than 25%; and a UWB device operating above 6 GHz would have a bandwidth greater than 1.5 GHz. In addition, it is proposed that the bandwidth should be based on the -10 dB point rather than the -20 dB point. The rational for using the -10 dB point is that the -20 dB point may be difficult to measure for many UWB devices. While this definition is viewed as technically appropriate, it was observed that the reference for the UWB definition states that only the fractional bandwidth should be greater than 0.25[1]. The fractional bandwidth is said to be the energy bandwidth. The energy bandwidth is defined as the frequency range within which some specified fraction, say 90 or 99 percent, of the total signal energy lies. This definition would appear to cover either the -10 or -20 dB bandwidth, whichever is preferable. Therefore -10 dB seems to be acceptable.

The NPRM also requests comment on whether the definition of UWB devices should be limited to devices that solely use pulsed emissions where the bandwidth is directly related to the narrow pulse width. The definition of UWB should involve only the bandwidth

[1] *Assessment of Ultra-Wideband (UWB) Technology*, OSD/DARPA, Ultra-Wideband Radar Review Panel, R-6280, Office of the Secretary of Defense, Defense Advanced Research Projects Agency, July 13, 1990.

and/or fractional bandwidth - if the NPRM needs to be restricted to UWB systems that use impulse-like signals, this can be stated without restricting the definition of UWB itself to impulse emitters only.

- **Paragraph 23:** The Commission indicated that several comments opposed the use of notch filters to reduce harmful interference to existing radio operations in the restricted frequency bands, TV broadcast bands, amateur radio frequency bands and others. The DoD believes this option should not be ruled out until measurement results demonstrate that no unacceptable interference will be caused to GPS reception and other critical services.

- **Paragraph 24:** The Part 15 restricted bands were selected on the basis of their use by, e.g., sensitive earth station receivers or aids to navigation used in the National Air Space (NAS). Although operated by the federal government, these systems perform functions critical to the public. We agree with the statement that critical systems in the restricted bands must be "protected against interference". To understand the technical and operational conditions under which UWB devices must be used to ensure this protection, credible analyses and measurements are required for the critical systems that must operate in these restricted bands. Historical antidotes and comparisons with unintentional radiators are insufficient evidence upon which to base national policy.

- **Paragraph 25:** We do not agree that the lack of historical evidence of harmful interference, or the projection of limited numbers, is sufficient in and of itself to conclude that Ground Penetrating Radars (GPRs) intended to be mass-marketed to the public will not cause interference to critical systems in the future. Neither of these arguments is sufficient to ensure interference-free operations of these devices under all likely scenarios in the future. We have concerns about the use of GPR devices below 2.29 GHz on a licensed or unlicensed basis until completion of UWB testing and its resulting demonstration that these devices will not cause unacceptable interference to GPS receptions in the 960-1215, 1559-1610, 1215-1300 and 2200-2290 MHz bands. We support the use of "kill" switches on GPRs to minimize risk of interference. Nevertheless, if the tests show interference even when these devices are aimed toward the ground, the manufacturer of these devices should be required to adjust UWB design to eliminate the interference potential such as additional shielding, notching out the GPS restricted bands or using alternative frequency bands. As previously stated, only credible analyses and measurements and a projection of the likelihood of the scenarios used in the analyses, are adequate to determine the potential interference impact of UWB devices. If these analyses and measurements have been made and show that this is an appropriate conclusion, they should be referenced and reviewed by all parties.

- **Paragraph 26:** Wall Penetrating Radars (WPRs) must be evaluated in the same fashion as GPRs or any other UWB device before appropriate emission level limits in restricted bands can be established. In response to the question asked in this paragraph of the NPRM, we are concerned about licensed use of WPR technology by parties eligible for licensing under the safety pool of frequencies in Part 90 if such operations require the use of spectrum in GPS bands or below 2.29 GHz. We are of the opinion that a decision on these uses should be deferred until after testing and analyses have been completed. We agree with the Commission that Wall Imaging Devices (WIDs) should incorporate design features that minimize power to the minimum necessary to function, such as automatic power control. Additionally, the test results and analyses may show that other design methods and operational procedures may be needed.

- **Paragraph 27:** The rationale for the statement that "UWB devices can generally operate in the regions of spectrum above approximately 2 GHz without causing harmful interference… due to high propagation losses" is not sufficient. Propagation path loss is only one factor in determining the potential for interference and does not dictate interference potential in and of itself. In addition, while directional antennas decrease the "likelihood" of interference coupling conditions, they also increase the interference potential when such coupling conditions do exist. Antenna directionality cannot be used to conclude that interference will not exist in the general sense, but can be used in developing appropriate operating conditions to reduce the potential for interference. Again, analytical and measurement evidence for each critical system in the restricted bands based on the expected use of UWB devices must be performed and presented before this conclusion can be reached. The DoD does not agree with the unlicensed use by UWB devices intended to be mass-marketed to business and the public of any of the restricted bands above about 2 GHz before this evidence is presented.

As an illustration of the impact of directional antennas on interference potential, analyses of projected aggregate environments of non-UWB emitters as possible interference sources to airborne radar have been performed. These analyses have led to the conclusion that the combined effects of these non-UWB emitters exceed a DoD established interference threshold when the radar antenna's mainbeam is in the direction of that environment, illuminating the surface of the earth from a distance. A preliminary analysis of the same geometrical situation was performed, with UWB emitters at the CFR Part 15 limits of EIRP = -41.2 dBm substituted for the non-UWB emitters. If a reasonable number of these emitters, e.g., one per square kilometer, were present in the environment, operating simultaneously, the interference threshold can be exceeded. Attachment 1 presents an interference assessment that shows a potential for interference to an airborne radar receiver. The attachment includes an emission level limit that, for this particular case, may avoid interference to the airborne radar analyzed.

- **Paragraph 28:** The Commission states that it is "particularly concerned about the impact of any potential interference to the GPS band at 1559-1610 MHz." It further states that they " also would be concerned about interference to any additional frequencies allocated to GPS, *e.g.*, the planned L5 frequency in the 960-1215 MHz band." We agree with the Commission and complement the Commission for soliciting comments regarding potential interference to GPS in the 1559-1610 MHz and 960-1215 MHz bands. We note that the L2 frequency band 1215-1300 MHz should also be included to protect current Government and possible public use of these GPS navigation signals. We also believe that the best method for evaluating interference potential is a thorough testing and analysis of UWB devices with a variety of civilian and military receivers.

- **Paragraph 29:** Paragraph 29 invites comments on UWB operations, potential restrictions on operation for UWB below 2 GHz, and the impacts such restrictions would have on any potential applications for UWB technology. Comment is also requested regarding the precise frequency below which operations of UWB devices may need to be restricted.[2] We note that since critical down-link telemetry and tracking data from DoD satellites, including GPS, is received by a network of sensitive earth station receivers that operate in the 2200-2290 MHz frequency band, we have particular concern regarding the effects of unlicensed UWB operations below 2290 MHz, vice 2 GHz, to ensure protection of these sensitive earth station receptions.

- **Paragraph 30:** Paragraph 30 invites comment on whether extremely low power devices may be allowed to operate in the restricted bands below 2 GHz and on how low power is to be defined. One approach would be to define "extremely low" such that peak levels at the IF output of a wideband receiver are 10 dB below noise at some reasonable distance. Effects of multiple emitters would have to be considered.

The loss of performance and cost increases associated with notching of frequencies in the restricted bands so as to prohibit the application of impulse radars or any other UWB device has not been demonstrated. If it can be shown that notching will prohibit these systems from operating as intended, then the restricted bands should be protected to levels that are consistent with levels that are demonstrated by testing and analysis not to cause unacceptable interference. Examples of previous protection requirements include

[2] Concern applies to all emissions within the –10 dB bandwidth of the UWB signal, not just at the center frequency.

those for IFF receivers at 1030 and 1090 MHz, and those for SARSAT receivers in the 406-MHz band[3,4].

In addition, we note that the military is highly dependent upon the 2200 - 2290 MHz restricted frequency band to receive critical data from DoD satellites Therefore, we have concerns if UWB devices intended to be mass-marketed to the public and business are allowed to use the spectrum below 2.29 GHz, vice 2.0 GHz. And we urge that case-by-case analyses be performed to establish if UWB devices can be allowed to operate in the restricted bands above 2.29 GHz. [Note: for consistency, we will use the term "about 2.0 GHz" in our comments.]

The DoD also urges that any conclusion regarding emission limits in any of the GPS frequency bands be deferred until the analysis and measurement activities are completed and the results thoroughly analyzed.

- **Paragraph 31:** We concur with the Commission's statement in paragraph 31 of the NPRM which states that, following the submission of test data, a public notice will be issued to provide an opportunity for comments and replies on the test results and analyses. On the other hand, we question whether the Commission's proposed October 30 target date for submitting test results provides adequate time to ensure that on-going and planned tests can be thoroughly completed and the results analyzed. The DoD notes that it is essential to ensure that tests results from both government agencies and

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[3] A. Baker and R. M. Williams, *Determination of Degradation Thresholds for the Search and Rescue Satellite (SARSAT),* ECAC-CR-84-050, DoD ECAC, Annapolis, MD, June 1984.
[4] International Radio Consultative Committee, *Compatibility Between Satellite EPIRBs Using the Band 406-406.1 MHz and Other Radio Services Using Adjacent Bands,* CCIR Report 1042, Geneva, Switzerland, 1990.

manufacturers be completed to enable general consensus to be reached concerning the potential UWB interference impact to existing systems. We therefore urge the Commission to postpone any decision on granting unlicensed operation of UWB devices until both government and manufacturers test programs are complete and the results analyzed.

- **Paragraph 33:** The characteristics requested for specific interference mechanisms include typical desired signal strengths. However, the onset of interference to critical systems in the restricted bands must be made using the minimum signal strength under which that system is expected to operate. Minimum signal strength should be included in this list.

- **Paragraphs 34 through 47:** The possibility of using scrambler techniques with UWB communications systems is discussed. Using scrambler techniques would help, but may not ensure a noise-like quality in all cases because the system response depends on system-receiver and UWB waveform parameters (such as receiver bandwidth, bit or chip rate, and UWB PRF).

It was also observed that emission limits should address both peak and average emissions in some manner. The DoD agrees with the Commission that the establishment of UWB emission limits must include consideration of both peak and average emissions. One approach is to place limits (within each frequency range) on the true average and the true peak emissions explicitly. A more practical approach may be to specify limits based on specific measurement procedures that may not actually provide true values for peak and average, but that have a well-defined relationship to peak and average emissions.

It is proposed in Paragraph 39 to use the general emission limits contained in 47 CFR Section 15.209 for UWB operations. It is also proposed that additional protection be provided below about 2 GHz. That is, for emissions below about 2 GHz from UWB devices other than ground-penetrating radars (GPRs) and possibly through-the-wall imaging systems, emissions should be attenuated 12 dB below the general emission limits. The NPRM invites comments as to whether this additional attenuation is necessary, whether additional protection may be necessary, and if such protection should only apply to the restricted bands. This reduction, whether it is 12 dB or some other value, would have to be determined through interference analysis and testing of the effects of an aggregate environment of UWB emitters operating at a reasonable minimum distance from the receivers in the restricted bands.

The effects of UWB devices operating in bands that are currently restricted, at emission limit levels proposed in the NPRM, have been investigated to a limited degree. Attachment 2 presents an assessment of the potential for interference to a multi-function earth station receiver. For the particular multi-function receiver addressed in the analysis, it was found that undesired interactions were predicted for separation distances slightly greater than 1.5 kilometers.

- **Paragraph 39:** The Commission has requested comment on whether such an attenuation level is necessary, or whether additional attenuation below 2 GHz is possible or necessary. Comment is also sought on whether the proposed reduction in the emission levels should apply to all emissions below 2 GHz or only to emissions below 2 GHz that fall within the restricted bands shown in 47 C.F.R. § 15.205. Comments also are requested on whether UWB devices other than GPRs, and possibly through-wall imaging systems, should be permitted to operate below 2 GHz provided they comply with these reduced emission levels. The DoD is of the opinion that additional attenuation may be necessary to protect GPS reception. However, any guidance regarding specific levels should await the completion of UWB testing with GPS receivers, and completion of analysis of the test results. It is expected that the test and analysis results may also be useful in determining whether additional attenuation levels should be applied to all emissions below 2.29 GHz or only to emissions within the restricted bands used by GPS.

- **Paragraph 40:** We agree with the FCC regarding the differences between intentional (i.e., UWB) and unintentional radiators/Class A digital devices, and the inappropriateness of outside of the building measurements.

- **Paragraphs 41 through 44:** The FCC proposes to limit peak emission levels and seeks comments on appropriate limits. For example, is a 20 dB peak to average limit in 50 MHz appropriate or would a limit defined by 20 + 20log(BW/50 MHz) be better? This is a significant issue and analyses of several test cases should be performed prior to adopting this proposal.

- **Paragraph 47:** We disagree that only the closest transmitter assumption is appropriate for all possible cases of "cumulative" interference. While this may be true for ground-based receivers in the midst of the emitter environment, the cumulative impact of multiple emitters can be a problem for airborne receivers and other receivers that are physically removed from the emitter environment, such as shipboard receivers at a distance from the shore. Attachment 1 presents an interference assessment that confirms the potential for interference to an airborne radar receiver from an aggregate environment of low-power UWB emitters. In other words, the airborne radar would be subjected to potential aggregate UWB interference from multiple low power emitters within the ground area illuminated by the antenna.

- **Paragraphs 48 through 54:** Measurement procedures are necessarily dependent on the specifications for emission limits. Some of the questions raised in the Measurement Procedures portion of the NPRM are more related to determining the appropriate method for specifying emission limits (e.g., Paragraph 48 excerpt: "Does the peak output level continue to be indicative of the interference potential of an UWB system?"). As previously stated, peak and average emissions both need to be addressed.

If true peak and average emissions are not specified/measured directly, the set of specified parameters to be measured must include quantities that are dependent on peak emissions and quantities that are dependent on average emissions (or a quantity that is dependent on both). The dependence should be such that, using these measured quantities, one should be able to distinguish between two signals having the same average emissions but different peak emissions, and vice-versa. The use of a quasi-peak detector below 1 GHz would appear to satisfy the requirement for a metric that addresses both peak and average emissions without actually providing true peak or average values.

Likewise, the proposal to specify/ measure average emissions in a 1 MHz band and peak emissions in a 50 MHz band (above 1 GHz) also addresses the requirement.

- **Paragraph 53:** Comments are requests on the use of a spectrum analyzer to perform peak measurements, noting that the applicant would need to show that the measurements, adjusted by the pulse desensitization correction factor (PDCF), indicate the true peak for the waveform being tested. For an individual applicant to demonstrate this would require access to another testing method that indicates the true peak (e.g., sampling oscilloscope measurements). If the applicant has access to such test equipment/methods, the need for the alternate (spectrum analyzer) method is eliminated. However, if analysis and testing (such as the efforts at NTIA/ITS and NIST) can demonstrate that the spectrum analyzer method, using readily calculated correction factors, can be used to determine the true peak for virtually all of the UWB signals of interest, then the rules could (and probably should) incorporate this measurement method.

- **Paragraph 54:** It is correctly stated that dispersionless antennas are required for accurate over-the air measurements of UWB signals. Acceptable antenna types need to be identified, and the rules need to specify that these types be used.

Also, it is recognized that the difference between the true peak and rms peak power levels is different for most impulse waveforms than it is for a sinusoidal waveform. Since there appears to be a limited number of waveshapes for impulse waveforms, it would seem that the relationships for sinusoidal pulses could be modified to apply to standard impulse waveforms. The true peak level could be obtained with a sampling oscilloscope. The relationships between peak voltage, peak power, and average power could be determined from consideration of each waveform type. An example of a comparison of peak instantaneous power versus average power (calculated and measured) for an impulse waveform is given in a JSC lab memo.[5] With the relationship between true peak power and the power measured by a spectrum analyzer determined, use of a spectrum analyzer may facilitate measurements.

III. CONCLUSIONS

The DoD considers the NPRM on UWB devices as a beginning towards appropriate regulation of the technical parameters and use of UWB devices intended to be mass-marketed to the public and businesses.. However, the DoD must be ensured that the use of these mass-marketed devices, either commercially or by the government, will not present unacceptable performance degradation to the systems used by the DoD for national security, especially for critical systems in the restricted bands.

The DoD urges the FCC to base any decisions on acceptable emission levels of UWB devices on credible analyses and measurements, and not on arguments emphasizing the lack of historical interference from Part 15 unintentional radiators or on the past use of the limited number of currently available UWB-type devices. As demonstrated in early analysis results referenced in the comments above, there is potential for interference within certain restricted bands under certain circumstances.

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[5] H. Martin, *UWB Peak and Average Powers*, JSC-LM#95-676, Annapolis, MD, DoD JSC, July 12, 1995.

As the FCC is aware, past and present uses of Part 15 devices or UWB-type devices does not represent the potential future scenarios that may occur. These future scenarios must be evaluated for interference potential and the likelihood of them occurring assessed. The DoD believes that the determination of potential impact of UWB devices to existing systems should be based on measurement results supplemented, when needed, by acceptable interference analysis procedures. In particular, we urge the Commission to allow sufficient time for both Government and industry to complete on-going and planned UWB-to-GPS interference test programs. Many of these analyses and measurements are ongoing and the DoD urges the FCC to await final decisions on the use of UWB devices on the outcome of these activities.

Attachments:

1. JSC analysis of airborne radar
2. JSC Analysis of Multifunction Earth Station Receiver

ATTACHMENT 1
EMC ASSESSMENT OF UWB DEVICES AND AN AIRBORNE RADAR RECEIVER

SECTION 1--INTRODUCTION

BACKGROUND

In the FCC Notice of Proposed Rulemaking, FCC 00-163,[1] the belief was stated that ultra-wideband (UWB) devices can generally operate in the region above approximately 2 GHz without causing harmful interference to other radio services. Accordingly, no frequency restrictions (i.e., restricted bands) for UWB devices operating above approximately 2 GHz were proposed.

Preliminary interference calculations were adapted from previous work with a large scale network of terrestrial emitters, postulated for the San Diego area, and an airbone early warning (AEW) radar receiver. These calculations indicated that it may be possible for signals from multiple UWB emitters radiating signals at the levels specified in Paragraph 15.209 of 47 of the Code of Federal Regulations (CFR),[2] to exceed the interference threshold of the radar, as specified by the radar program office.

OBJECTIVE

The objective of this study was to assess the effects of multiple UWB emitters operating above 2 GHz on selected radar receivers.

APPROACH

The effects of aggregate UWB emitters were calculated for the SEEK SKYHOOK radar receiver. The geometrical configuration used in the AEW radar receiver analysis for the San Diego area (mentioned in the Background) was adapted for use in analyzing the SEEK SKYHOOK radar receiver. The receiver and antenna characteristics of the radar were obtained from technical literature.[3] Using the effective isotropic radiated power (EIRP) levels derived from the FCC rules, and specified interference thresholds, the number of UWB emitters necessary to exceed each threshold was calculated. This number was divided by the area illuminated by the radar antenna mainbeam. The resulting, number is the estimated emitter density needed to exceed the specified interference threshold. This emitter density was compared with values expected for various UWB applications. When this maximum emitter density was less than the values expected from the aggregate environment, a lowered maximum EIRP value, such that the threshold would not be exceeded, was calculated. Where appropriate, additional factors that would mitigate the results are described. These factors include non-constant antenna gain and intermittent operation.

SECTION 2—RADAR SYSTEM DESCRIPTION—AN/DPS-5 SEEK SKYHOOK

The AN/DPS-5 SEEK SKYHOOK is a surveillance radar used to detect low flying aircraft from a tethered balloon positioned 12,000 ft above mean sea level (MSL). The radar system has a range of 278 km at an altitude of 3660 m. It is used by the US Air Force, the US Coast Guard, and others for air defense, law enforcement, and drug interdiction. At present, drug interdiction is its primary role and it is currently stationed only at Cudjoe Key, FL.

RECEIVER CHARACTERISTICS

The SEEK SKYHOOK radar receiver operates at 3.15 and 3.23 GHz. The radar beacon digitizer includes capabilities for clutter mapping, target sorting, and use of target track history. The radar ground subsystem has a digital processor with the capability of simultaneous operation with two other systems on the platform. Normal and moving target indicator (MTI) radar video are selectable with or without constant false alarm rate (CFAR) threshold determination. The display can be either on a plan-position indicator (PPI) or digitized video. Receiver technical characteristics relevant to the analysis are provided in Table 2-1.

ANTENNA CHARACTERISTICS

The SEEK SKYHOOK employs a rotating S-band parabolic reflector antenna, shaped to generate a gain pattern that is proportional to the square of the cosecant of the elevation angle. The polarization is user-selectable, directed circular and horizontal or vertical and horizontal. Technical characteristics of this antenna relevant to the analysis are provided in Table 2-2.

Table 2-1. SEEK SKYHOOK Receiver Technical Characteristics

Characteristic	Value
Nominal Frequency Range (MHz)	3100-3300
IF Frequency (MHz)	30
RF Bandwidth (MHz)	
-3 dB level	20
-20 dB level	40
-60 dB level	60
IF Bandwidth (MHz)	
-3 dB level	0.67
-20 dB level	3.50
-60 dB level	10.0
Sensitivity (dBm)	-112
Sensitivity Criteria	0 dB S/N

Table 2-2. SEEK SKYHOOK Antenna Technical Characteristics

Characteristic	Value
Mainbeam Gain (dBi)	40
Beamwidth (deg)	
Horizontal	1.0
Vertical	2.2
Scan Coverage (deg)	360
Scan Rate (rpm)	5.0
Antenna Tilt (deg)	-1.5

SECTION 3--ANALYSIS

ENVIRONMENT AREA

In earlier analyses of the impact of FWA transmitters on an airborne radar, network designs were postulated to cover two metropolitan areas: San Diego, CA, and Seattle, WA. For each area maps were provided and base stations were located, with cells and their associated sectors plotted. For this analysis, geographical areas similar to those occupied by the networks were assumed to be occupied by UWB devices at postulated densities. This investigation was initially limited to the San Diego area.

The area considered in the FWA network was approximately contiguous with the Rand McNally Ranally Metro Area (RMA),[4] and contains most of the urban and suburban areas of that RMA. The RMA contains a population of 2,781,800 (1999 estimate) within 1373 square miles (2590 square kilometers). The number of households was calculated according to the proportion of population in the overall Office of Management and Budget (OMB) Metropolitan Statistical Area (MSA) which is used by the US Census Bureau, as about 94.9 percent of 991,100, or 940,560. The irregularly shaped network area was 120 km long (along the coast) by 42 km wide (at the widest point).

TRANSMITTER-RECEIVER GEOMETRY

Analysis of the geometry of the UWB environment for the AN/DPS-5 was done in a manner similar to that of the previous analysis. The AN/DPS-5 radar is at a nominal altitude of 12,000 feet and the 1.235 earth's radius model was used. The antenna pattern below the mainbeam axis was calculated from the two-way gain data given in Figure 1 of a previous Radar Evaluation Report. Because of the narrow (2.2-degree) vertical beamwidth, two geometrical situations were analyzed: 1) a "two-patch" model and a single-patch model. In the two-patch model, the footprints corresponding to two elevation sectors were calculated and used, a one-degree sector above a contiguous two-degree sector. In the single patch model, only the one-degree sector was used. In each case, the edge of the footprint closest to the radar coincided with the near edge of the deployment. The AN/DPS-5 elevation angle was –1.5 degrees. The propagation loss at a distance corresponding to the center of each footprint was calculated using a smooth-earth model. If the footprint extended beyond the limits of the finite environment, the center of that portion of the environment overlapped by the footprint was used to calculate the propagation loss.

The elevation angle to the horizon for a 12,000 foot altitude was calculated to be –1.75 degrees. Calculations of the length of the footprint were performed by applying the law of sines to a 1.235 radius spherical earth model. The width of the footprint was calculated using a flat-earth approximation applied to the footprint center.

The footprints were assumed to lie along the longer dimension of the environment, which was 120 km for the San Diego environment. Characteristics of the elevation sector footprints are shown in Table 3-1.

Table 3-1. Characteristics of Elevation Sector Footprints, AN/DPS-5 SEEK SKYHOOK Radar

Elevation Sector	Dimensions of Footprint		Range to Center, km	Approx. Area, km^2	Path Loss to Center, dB
	Length, km	Width, km			
1 (Two-Patch) (-1.75 to –2.75 degs)	143.5 (71.8)[a]	2.94	168.2 (132.3)[a]	210.6	139.3
2 (Two-Patch) (-2.75 to –4.75 degs)	48.2	1.264	72.3	60.9	134.6
1 (Single Patch)	143.5 (120)[a]	2.94	168.2 (156.4)[a]	352.4	140.7

[a] Numbers in parentheses apply to area of overlap with environment.

CALCULATION OF DENSITY OF EMITTERS NECESSARY TO EXCEED INTERFERENCE THRESHOLD

The power from a single emitter in the geographical area illuminated by the radar antenna mainbeam was calculated using Equation 3-1:

$$P_R = EIRP + G_R - L_P - L_R + 10 \log Br \qquad (3\text{-}1)$$

Where:

P_R = interference power in victim receiver, in dBm

EIRP	=	effective isotropic radiated power spectral density (transmitter power spectral density in dBm/MHz plus antenna gain in dBi) of a UWB device
G_R	=	receiver antenna gain, in dBi
L_P	=	propagation path loss, in dB
L_R	=	receiver system loss, 1.8 dB
Br	=	receiver IF bandwidth, in MHz.

The propagation path loss used was calculated for the center of each sector.

The value of EIRP in Equation 3-1 was determined from the value in FCC 47 CFR 15.209, which is specified as an average (rms) field strength of 500 microvolts/meter at 3 meters from the source, for frequencies above 960 MHz. This level is specified in a 1-MHz bandwidth. The power density, in dBm/m^2 (in a 1-MHz bandwidth), was calculated using Equation 3-2:

$$P_D = 10 \log (E^2/377) - 90 \qquad (3\text{-}2)$$

Where:

E = specified rms field strength, microvolts/meter, in a 1-MHz bandwidth.

The EIRP was then calculated from Equation 3-3:

$$EIRP = P_D + 20 \log R + 10.99 \qquad (3\text{-}3)$$

Where:

R = distance in meters.

For R = 3 meters, EIRP = -41.2 dBm/MHz.

The total power p_r received (in a 1-MHz bandwidth) was calculated by summing the power from each sector, as defined in Equation 3-4:

$$p_r = d \sum_{i=1}^{n} p_i a_i \qquad (3\text{-}4)$$

where:

p_i	=	received power from a single emitter at the center of each area illuminated, in mw
a_i	=	area illuminated in a given sector, km^2
d	=	density of emitters, in emitters/km^2.

The UWB emitters were assumed to be uniformly distributed in the area illuminated.

For a given interference threshold i_t, in milliwatts, the density d of emitters per km^2 needed to exceed the interference threshold was calculated using Equation 3-5:

$$d = \frac{i_t}{\sum_{i=1}^{n} p_i a_i} \tag{3-5}$$

where:

i_t	=	interference threshold, in milliwatts
p_i	=	received power from a single emitter in the center of area i (given by Equation 1 in dBm), in mw.
a_i	=	area i illuminated by sector i in km^2.

For the sectors illuminated by the SEEK SKYHOOK antenna, and the two geometrical situations described earlier (one patch and two patches), results were calculated for three interference thresholds, I/N = -3 dB, -6 dB, and –10 dB. Calculated values of emitter density in emitters per square kilometer needed to exceed the interference threshold are given in Table 3-2.

Table 3-2. Calculated Values of UWB Emitter Density, in Emitters/Km², Needed to Exceed Threshold for AN/DPS-5 SEEK SKYHOOK Radar

Geometry	Interference Threshold, I/N, in dB		
	-10	-6	-3
One Patch	0.410	1.030	2.06
Two Patches	0.377	0.946	1.888

The emitter densities calculated were based on average power. If the time interval between the pulses is jittered from pulse to pulse, as is the case with some UWB emitters, this analysis is valid. If the PRF is constant, the signal may form a series of spectral lines in the frequency domain. The spectral lines are separated by the pulse repetition frequency (PRF) of the emitter.

When the PRF is greater than the receiver bandwidth, the UWB emitter can be designed such that the PRF lines fall on either side of the receiver frequency and outside its passband, restricting the interference to that entering through the skirts of the receiver selectivity. For the purposes of this analysis, however, the relative frequency separation of the PRF lines and receiver frequency was assumed to be random for each emitter. A probability ρ is associated with the coincidence of the PRF line and the receiver passband. The probability ρ is given by Equation 3-6:

$$\rho = \begin{cases} Br / PRF & ; PRF > Br \\ 1 & ; PRF \leq Br \end{cases} \qquad (3\text{-}6)$$

where:

Br	=	the receiver IF bandwidth, in Hertz
PRF	=	the UWB emitter PRF, in Hertz.

The emitter density d required for the interference threshold i_t to be exceeded is calculated as follows. From Equation 3-5:

$$d = \frac{i_t}{\sum_{i=1}^{n} p_i a_i} \qquad (3\text{-}7)$$

or:

$$d = \frac{i_t}{p_t g_t g_r B_r \sum_{i=1}^{n} \frac{a_i}{l_{pi}}} \qquad (3\text{-}8)$$

where:

p_t	=	power spectral density, or p_{ave}/B_t, in mw/Hz
B_t	=	transmitter bandwidth, in Hz
g_t	=	transmitter antenna gain (absolute value)

g_r	=	receiver antenna gain (absolute value)
l_{pi}	=	path loss to area i (absolute value)

and other quantities are as defined earlier.

Therefore:

$$d = \frac{\dot{i}_t}{\left(\frac{p_{ave}}{B_t}\right) B_r \left[g_t g_r \sum_{i=1}^{n} \frac{a_i}{l_{pi}} \right]} \tag{3-9}$$

The power in a spectral line $p_{sl} = p_{ave}\, \tau\, (PRF)$, where τ and PRF are the pulsewidth and pulse repetition rate of the UWB impulse waveform, respectively. Therefore:

$$d = \frac{\dot{i}_t}{\left(\frac{p_{sl}}{\tau (PRF) B_t}\right) B_r \left[g_t g_r \sum_{i=1}^{n} \frac{a_i}{l_{pi}} \right]} \tag{3-10}$$

But $B_t\, \tau = 1$ and $\rho = B_r / PRF$. Therefore:

$$d = \frac{\dot{i}_t}{p_{sl} \rho \left[g_t g_r \sum_{i=1}^{n} \frac{a_i}{l_{pi}} \right]} \tag{3-11}$$

Equation 3-11 is equivalent to Equation 3-4 and can be written as Equation 3-12:

$$d = \frac{\dot{i}_t}{\rho \sum_{i=1}^{n} p_{sli} a_i} \tag{3-12}$$

where p_{sli} is the power from a spectral line from a single emitter in area a_i, and other quantities are as previously defined.

Calculations for several UWB emitters with PRFs from 1 MHz to 10 MHz have demonstrated that the allowable densities are the same for constant PRF emitters with randomly placed PRFs as for staggered PRF emitters.

The threshold I/N = -3 dB is equivalent to a 10 percent loss in detection range, and was used in the earlier analysis of the AN/DPS-5 (SEEK SKYHOOK) radar. The more conservative threshold I/N = -6 dB is equivalent to an approximate 5 percent loss in detection range and has been used in many previous EMC analyses. The threshold I/N = -10 dB is a very conservative threshold and equates to approximately 3 percent loss in detection range.

The analysis performed applies only to the mainbeam conditions where the interfering emitters are in the mainbeam of the radar. The radar would be desensitized only in the direction of the UWB emitter environment, e.g., when the radar is illuminating the San Diego area.

COMPARISON WITH EXPECTED DENSITIES OF CERTAIN TYPES OF UWB EMITTERS

Residential Intrusion Detectors

One of the proposed applications of low-power UWB radars is as intrusion detectors for residences. In the San Diego area, there are approximately 940,560 homes in a 1373 square-mile area (3556 square kilometers). This equates to 264 homes per square kilometer. If one percent of these homes have intrusion detectors, operating continuously, the density, 2.64 homes per square kilometer, is larger than the 1.89 emitters/square kilometer given in Table 3-2 for the I/N = -3 dB threshold.

Automotive Collision Avoidance Radars.

In automotive noise studies, it was stated that "Off hour traffic corresponds to a few cars per minute while rush hour traffic reaches sustained proportions of about 100 cars per minute."[5] Two values of vehicle frequency, 100 cars per minute (rush-hour) and 10 cars per minute (off-hour), were used in this analysis. The number of cars per mile was calculated using Equation 3-13:

$$D_T = F_T/V_T \tag{3-13}$$

where:

D_T	=	traffic density, cars per mile
F_T	=	traffic vehicle frequency, cars per minute
V_T	=	average vehicle speed, miles/min.

Two values of V_T were selected, 60 miles per hour (1 mile per minute) and 30 miles per hour (0.5 miles per minute).

The San Diego area has 902.9 miles of highway in a 4208.5 square mile area.[6] The rural part of this area is 3338 square miles, or 80 percent of the total. Twenty-five percent of this mileage is interstate highway. The highway mileage is assumed to be spread equally over the total area (urban, suburban, and rural) for a density of 0.0828 mile/square kilometer.

The density of cars per square kilometer was calculated by multiplying the number of cars per mile times the miles of highway per square kilometer. Results are given in Table 3-3.

Table 3-3. Vehicle Densities for Different Traffic Conditions

Condition	Speed, mph	Cars/minute	Cars/mile	Cars/km^2
Rush Hour	60	100	100	8.3
Rush Hour	30	100	200	16.6
Light Traffic	60	10	10	0.83
Light Traffic	30	10	20	1.66

Comparison of the results in Table 3-3 with the densities needed for the interference threshold to be exceeded, given in Table 3-2, leads to the conclusion that light traffic would probably not exceed the interference threshold (I/N = -3 dB) used in previous SEEK SKYHOOK analyses. However, it could exceed the densities corresponding to the lower thresholds considered. Also, intermediate and higher traffic levels as shown could exceed the densities that cause the thresholds to be exceeded.

Combined Effects

Two classes of emitters, intrusion detectors and automotive collision avoidance radars, were analyzed separately to determine their aggregate effect on a radar receiver. In reality, both types of emitters would be present in a given environment. The power from each class would be added, and the allowable numbers of each would be decreased.

SUGGESTED MAXIMUM EIRP LEVELS

Values of maximum EIRP, in dBm/MHz were calculated, based on the expected density of emitters in an environment, such that the interference threshold selected was not exceeded. Values were calculated using Equation 3-14:

$$EIRP_2 = EIRP_1 - 10 \log (d_2 / d_1) \qquad (3\text{-}14)$$

Where:

$EIRP_2$ = maximum EIRP, in dBm/MHz
$EIRP_1$ = -41.2 dBm/MHz (from 47 CFR Par. 15.209)
d_2 = density of emitters in environment, emitters/km^2
d_1 = density of emitters needed to exceed threshold.

Values of d_1 are given in Table 3-2.

For residential intrusion detectors, if all homes were using the UWB devices, an EIRP of –62.7 dBm/MHz or less would be needed to avoid exceeding the -3 dB I/N threshold level. If one percent of the homes use the UWB devices, -42.7 dBm/MHz would be needed. For ten percent, -52.7 dBm/MHz should not be exceeded. For automotive collision avoidance radars in rush hour traffic at a speed of 30 miles per hour, -50.6 dBm/MHz would be needed. A value of –50.6 dBm would be equivalent to 169 microvolts per meter at three meters from the source, while –52.7 dBm is equivalent to 133 microvolts per meter. It appears that a value of –53 dBm (129 microvolts per meter) would cover most interference situations analyzed in this study.

EMI MITIGATING FACTORS

A number of factors are expected to mitigate the results of the analysis presented above. The analysis was based on conservative assumptions, and several factors could reduce the I/N levels from those predicted. However, because of a lack of information, they were not included in the baseline analysis. These factors include antenna pattern effects, intermittent operation, and additional attenuation of the UWB emitter signals due to blockage from terrain, buildings, trees, and vegetation.

Antenna Patterns

Antenna gains of UWB transmitters are expected to vary with the relative orientation between transmitter and receiver. An NTIA paper[7] shows a typical "antenna pattern" for an unlicensed radio device and states that the mean "gain" might be 5 dB or more below the peak value. If the value of EIRP specified in 47 CFR 15.209 is the maximum value, the allowable density of emitters could be increased for a given interference situation.

Also, for the devices considered, intrusion detectors and automotive radars, the antenna gain might decrease with elevation, although the elevation angles considered, 1 to 5 degrees, are relatively small.

Intermittent Operation

In the analysis, it was assumed that the devices were operating continuously. Intermittent operation of any UWB device will increase the number allowable, on the average, for compatible operation. As shown in Reference 12, an activity factor, or percentage of on-time, of 1 per cent, would result in a decrease in the relative interference level of 20 dB, or an increase in the allowable density of a factor of 100. However, it is expected that, when installed, intrusion detectors would be operated 100 percent of the time and automotive collision avoidance radars would operate whenever the automobile is on the road.

Building Attenuation Losses

When UWB devices are located inside buildings, additional attenuation losses occur, due to the signal passing through walls and windows of the building. At the frequencies of concern here (3 GHz), these losses vary from 5 to 10 dB (Reference 12).

Attenuation by Obstacles

A smooth-earth propagation model was used in this analysis. However, in general, some attenuation by obstacles between the transmitter and receiver can be expected. These obstacles include terrain, buildings, trees, and vegetation. For an extended path, such as the ones considered here, this excess path loss is difficult to predict.

SECTION 4—RESULTS

The density of UWB emitters, meeting the EIRP restrictions of 47 CFR 15.209, needed to exceed the interference threshold of the AN/DPS-5 SEEK SKYHOOK surveillance radar, was calculated. The calculations were performed for a specific situation where the SEEK SKYHOOK radar was pointed in the direction of a given environment, at a distance where the mainbeam of that radar illuminates the area occupied by the emitters.

It was found that, for the conditions specified, 1.9 emitters per square kilometer would cause the interference threshold to be exceeded. For two applications, residential intrusion detectors and automotive collision avoidance radars, it appears that conditions exist under which that density could be exceeded.

It appears that lowering the maximum EIRP to –53 dBm, which is equivalent to 129 microvolts per meter at three meters, would reduce the interference from most aggregate environments to below the threshold level considered.

Certain factors, such as variable antenna gain, intermittent operation, attenuation caused by operation inside buildings, and attenuation by obstacles such as terrain, buildings, trees, and vegetation could reduce the predicted interference levels. Many of these effects are difficult to predict quantitatively. The qualitative effect of each factor was commented on, as it applied to the UWB devices considered.

REFERENCES

[1] FCC Notice of Proposed Rule Making (NPRM), FCC 00-163, ET Docket No. 98-153, Washington, DC, Federal Communications Commission, May 11, 2000.

[2] Code of Federal Regulations, 47 CFR 15.209, Washington, DC: US Government Printing Office, October 1999.

[3] ITU Radiocommunication Study Groups, Sharing Assessment Between Systems in the Radiolocation Service and One FWA System Operating in the 3400-3700 MHz Band, Document 8A9B/ 173, Attachment 4, 8 March 2000.

[4] Rand McNally 2000 Commercial Atlas and Marketing Guide, Rand McNally, 2000.

[5] W. G. Duff and D. R. J. White, *EMI Prediction and Analysis Techniques,* Volume 5 of *A Handbook Series on Electromagnetic* Interference *and Compatibility,* Germantown, MD: Don White Consultants, 1972, p. 7.27.

[6] NORTEL Memorandum dated 15 April 1998. Subject: JSC Top Level Radio Planning.

[7] Gerald F. Hurt, "Unlicensed Radio Devices," *1999 International Ultra Wideband Conference,* Washington, DC, September 28-30, 1999.

ATTACHMENT 2

EMC ASSESSMENT OF UWB DEVICES AND A MULTI-FUNCTION EARTH STATION RECEIVER

SECTION 1 - INTRODUCTION

BACKGROUND

The Federal Communications Commission (FCC) has issued a Notice of Proposed Rulemaking (NPRM)[1] that would revise sections of Part 15 of Title 47 of the Code of Federal Regulations (CFR). These revisions would allow certain low-power Ultra-WideBand (UWB) systems to operate as unlicensed devices. In the NPRM it is proposed that UWB devices can generally operate above 2 GHz without causing harmful interference to other radio services, provided that the emissions of the devices do not exceed the emission limit levels in 15.209 of Part 15. As a consequence of this proposal UWB fundamental emissions could now occur in many frequency bands that were previously considered restricted bands (15.205).

One of the restricted bands is the frequency range 2200-2300 MHz. This band is used extensively by the Department of Defense (DoD) to support Tracking, Telemetry, and Command (TT&C), as well as other functions, of most DoD space based assets. The part of the DoD satellite control network that uses this frequency range is the downlink of the Space-Ground Link Subsystem (SGLS). Concerns have been expressed regarding the potential for degradation to SGLS receivers if UWB devices can now operate in the 2200-2300 MHz frequency range.

OBJECTIVE

The objective of this effort was to assess the effects of low-power UWB emitters on the operations of SGLS receivers.

APPROACH

A description of the SGLS downlink operations and associated operational parameters were obtained from technical literature. The values of the technical characteristics used in the following analysis were also obtained from the technical literature.

The power level limits proposed in Reference 1 were used to determine the maximum effective isotropic radiated power (EIRP) of an UWB device operating at 2 GHz. Possible pulse repetition rates were obtained from applications for waivers for several UWB systems.

Using UWB emission parameters and SGLS receiver characteristics the minimum separation distance required to prevent interference thresholds from being exceeded by a single UWB emitter were determined. If required separation distances were large then the effects of multiple emitters would be assessed.

SECTION 2 - SYSTEM DESCRIPTION

The Air Force Satellite Control Network (AFSCN) provides tracking, telemetry, command, control, and communications functions for manned and unmanned DoD and non-DoD satellite operations and other space vehicle missions. The terrestrial components of the AFSCN include operations control nodes, common-user control nodes, remote ground facilities, remote tracking stations, and automated remote tracking stations. One element of the AFSCN is the Space Ground Link Subsystem (SGLS) which provides TT&C, as well as data and voice communications. The SGLS uplink operates between 1760-1845 MHz and the downlink operates between 2200-2290 MHz.

The SGLS downlink signal format can include any combination of ranging code and three subcarriers (carrier 1), telemetry (carrier 2), and wideband data (carrier 3). Selected downlink signal parameters relevant to this assessment are provided in Table 1 below. Certain space vehicles may include a special S-band communications package that accommodates three carriers on a standard SGLS link. This is referred to as the M2P1 configuration and provides additional voice and data communications. For the terminals examined in this analysis, a review of the M2P1 characteristics shows the standard SGLS downlink to be more susceptible to interference than the M2P1 downlink. Consequently, the M2P1 receiver analysis is not presented here.

Table 1. Nominal SGLS Downlink Signal Characteristics

Nominal SGLS Earth Station Parameter	Value
3 dB Bandwidth/Bit Rate	Carrier 1 1.024 MHz subcarrier PCM telemetry 7.8 bps -128 kbps 1.25 MHz subcarrier Voice 100 Hz - 3.5 kHz Analog data 100 Hz - 20 kHz 1.7 MHz subcarrier PCM/PAM telemetry 125 bps - 256 kbps PAM telemetry to 20 kHz 2.05 kHz Carrier 2 128 - 1024 kbps Carrier 3 0.2 - 10 MHz

AFSCN earth stations that receive the SGLS downlink signals are limited in number and are normally fixed facilities located at government controlled sites. The fixed terminals generally include large, high gain, directional antennas. Within the control network there are smaller, transportable terminals that function as remote tracking stations and may be used for range operations and special events. These transportable terminals were the initial focus of this assessment as these terminals are the most likely to be near an uncontrolled environment, have lower link margins due to smaller antennas, and consequently may be more subject to interference.

The transportable terminals include the S-band transportable ground station (STGS), the transportable S-band terminal (TST), and the transportable space test and evaluation resource (TSTR). Of these terminals, the TST has the smallest antenna, the lower figure of merit, lowest link margin, and has the lowest interference thresholds. However, the TST only uses carriers 1 and 2. The STGS uses carrier 3 and has a lower interference threshold than the TSTR. This assessment is performed for the TST and the STGS using carrier 3 with the expectation that required separation distances for these terminals would be the greatest of the various earth stations that receive the SGLS downlink. Relevant SGLS parameters are included in Table 2 below.

Table 2. SGLS Link Budget Values

Item	TST Carrier 1			TST Carrier 2		STGS Carrier 3
	Telemetry	Comm	Ranging	512 kbps	1024 kbps	10 MHz
Effective Received Power (dBm)	-110.6	-113.2	-108.1	-101.1	-101.1	-98.0
Effective Noise Temperature (dBk)	22.9	22.9	22.9	22.9	22.9	22.9
N_0 (dBm/Hz)	-175.7	-175.7	-175.7	-175.7	-175.7	-175.7
Bandwidth (dBHz)	45.0	43.0	60.0	57.1	60.1	70.0
E_b/N_0 (dB) C/N_0 (dB)	20.1	 22.1	 67.6	17.5	14.5	 10.7
E_b/N_0 Required (dB) C/N_0 Required (dB)	9.6	 -23.0	 47	9.6	9.6	 6.6
Link Margin (dB)	10.5	25.1	20.6	7.9	4.9	4.1
Required Margin (dB)	3.0	3.0	3.0	3.0	3.0	3.0
Excess Margin (dB)	7.5	22.0	17.6	4.9	1.9	1.1
N (dBm)	-130.7	-132.7	-115.7	-118.6	-115.6	-105.7
I/N_{th} (dB)	6.7	8.5	17.5	3.2	-2.6	-5.4
Interference threshold, I_{th}, dBm	-124.0	-110.7	-98.2	-115.4	-118.2	-111.1

SECTION 3 - ANALYSIS

The EIRP of the UWB device considered in this analysis can be determined from the NPRM and from paragraph 15.209 of Part 15, Title 47 of the CFR. According to the NPRM the maximum average power limit on an unlicensed low-power UWB device would be as specified in 15.209 of the current Part 15. This limit is specified for systems operating above 960 MHz as a field strength of 500 microvolts per meter at a distance of 3 meters in a 1 MHz bandwidth. The EIRP corresponding to this field strength is determined using Equation 1 below,

$$e = \frac{(30*P_t)^{1/2}}{d} \qquad (1)$$

where,

e = field strength in volts/meter,

P_t = transmit EIRP in watts, and

d = distance at which e is determined in meters.

Solving equation 1 for $e = 500$ µvolts/meter and $r = 3$ meters gives an EIRP, P_t, expressed in dBm of -41.2 dBm in a 1 MHz bandwidth. This EIRP was used as the maximum average power of a UWB device in this analysis.

Interference thresholds presented in Table 2 were used for each of the SGLS downlink functions considered in the analysis. These are interfering signal level thresholds calculated based on the predicted downlink signal strength, system noise levels, required C/N_o, and excess margin. The assumption is made that the interference is noiselike. This assumption is considered reasonable in those cases where the pulse repetition frequency (PRF) of a UWB interfering source is greater than or equal to the bit rate of the SGLS downlink function being considered. Of the three transportable terminals, the TST and the STGS have the lowest interference thresholds and would require the greatest separation distances from interfering UWB devices. The thresholds for these terminals are provided in Table 2 above.

With known UWB EIRP and SGLS downlink interference thresholds, the separation distance needed to prevent interference was determined. Equation 2 below was the basis for determining this distance.

$$I_{th} = P_t + G_t + G_r - L_p + 10\log B_r \qquad (2)$$

where,

I_{th} = Interference threshold of the SGLS receiver in dBm,
P_t = Transmit power of the interfering source in dBm,
G_t = Transmit antenna gain of the interfering source in the direction of the victim receiver in dBi,
G_r = Receive antenna gain of the victim receiver in the direction of the interfering source in dBi,
L_p = Propagation loss between interfering source and victim receiver in dB, and
B_r = Victim receiver bandwidth, in MHz.

In Equation 2 the propagation loss can be calculated as below

$$L_p = 20\log f + 20\log d - 27.5 \qquad (3)$$

where,

f = Frequency in MHz and
d = Separation distance in meters.

Lp is as previously defined. Also, $P_t + G_t$ is equivalent to the EIRP previously calculated as -41.2 dBm in a 1 MHz bandwidth. The separation distance required to insure that interference thresholds are not exceeded can be determined by making substitutions in Equation 2 and solving for d in meters.

$$d = \log^{-1}\left[\frac{EIRP + G_r - 20\log f + 27.5 + 10\log B_r - I_{th}}{20}\right] \qquad (4)$$

Table 3 below presents the calculated required separation distances, d in meters, for the various modes of operation of the TST and STGS SGLS units. For the purposes of this assessment 2200 MHz was assumed for the operating frequency, f, and values of B_r are included in Table 2. Required separation distances were calculated for several receive antenna elevation angles as shown in Table 3. Values of the SGLS terminal receiver antenna gain towards the horizon, G_r in dBi, are also shown in Table 3 and were obtained from the technical literature.

Table 3. Calculated Required Separation Distances

Receive Antenna Elevation Angle, degrees	SGLS Downlink Function											
	TST Carrier 1						TST Carrier 2				STGS Carrier 3	
	Telemetry		Comm		Ranging		512 kbps		1024 kbps		8000 kbps	
	G_r, dBi	[redacted]	G_r, dBi	[redacted]	G_r, dBi	[redacted]	G_r, dBi	[redacted]	G_r, dBi	[redacted]	G_r, dBi	[redacted]
20	8	[redacted]	8	[redacted]	8	[redacted]	8	[redacted]	8	[redacted]	6	[redacted]
10	16	[redacted]	16	[redacted]	16	[redacted]	16	[redacted]	16	[redacted]	14	[redacted]
5	19	[redacted]	19	[redacted]	19	[redacted]	19	[redacted]	19	[redacted]	22	[redacted]
3	26	[redacted]	26	[redacted]	26	[redacted]	26	[redacted]	26	[redacted]	23	[redacted]

Examination of the required separation distances shows these distances to be in excessive of a kilometer for several modes of operation.

SECTION 4 - RESULTS

The separation distances required to prevent interference to AFSCN TST and STGS earth terminals from a low-power UWB device were calculated. It was found that for several modes of earth terminal operation the required separation distances were in excess of one kilometer.

REFERENCES

[1] FCC Notice of Proposed Rule Making (NPRM), FCC 00-163, ET Docket No. 98-153, Washington, DC, Federal Communications Commission, May 11, 2000.